# Changes in the Species Composition of the Fish Community in a Reach of the Kootenai River, Idaho, after Construction of Libby Dam

**Vaughn L. Paragamian**

*Idaho Department of Fish and Game*
*2750 Kathleen Avenue*
*Coeur d'Alene, !D 83815 USA*
*E-mail: vparagam@idfg.state.id.us*

## ABSTRACT

I evaluated fish community structure and the density and growth of mountain whitefish (Prosopium williamsoni) downstream of Libby Dam in a 1.0-km reach of the Kootenai River, Idaho, in 1994 and compared the results with those of a similar study in 1980, after closure of the dam. In 1980 seven species of fish were collected; mountain whitefish comprised 70% of the sample (42% by weight), and largescale sucker (Catostomus macrocheilus) represented 19% of the sample (49% by weight). In 1994 of the eight species caught, mountain whitefish represented only 40% by number (19% by weight), and the largescale sucker was 65% of the sample (70% by weight). Growth of mountain whitefish was also slower in the early 1990s compared to the later 1970s. Reduced productivity because of the nutrient sink effect of Lake Koocanusa, river regulation, the lack of flushing flows, power peaking, and changes in river temperature may have led to the changes in the fish community structure.

## INTRODUCTION

The aging process within reservoirs of the eastern USA is fairly well understood (Baxter 1977, Yurk and Ney 1989, Ney et al. 1990, Ney 1996); but less, is known of the process in reservoirs of the western USA and the main stem rivers downstream. Typically new reservoirs are not stable and are closer to riverine systems in productivity, but as they age the systems change because of nutrient binding in bottom sediments. Usually fish populations and communities change in conjunction with decreases in productivity (Yurk and Ney 1989, Peňáz et al. 1999). For example, changes in seasonal flow patterns, dewatering of varial zones, loss of flushing flows, and temperature changes are known to play roles in altering the fish species composition and life history characteristics (Benenati et al. 1998, Bain et al. 1988, Binn et al. 1995, McKinney et al. 2001).

Since the late 1800s the Kootenai River in Montana and Idaho, USA and British Columbia, Canada has undergone many anthropogenic changes (Northcote 1973, Daily et al. 1981, Anonymous 1996). The most pronounced effect was the construction and operation of Libby Dam, Montana (Partridge 1983, Apperson 1990) (Figure 1). Operation of Libby Dam for flood control and hydropower changed the river's seasonal hydrograph and thermal regime. Libby Dam is also a power peaking facility with daily flows ranging from 113 $m^3/s$ to 708 $m^3/s$. These changes contributed to the collapse of the burbot (Lota lota) population (Paragamian et al. 2000) and to declines in white sturgeon (Acipenser transmontanus; Partridge 1983, Apperson 1990) and kokanee (Oncorhynchus nerka; Partridge 1983) in the Kootenai River below Libby Dam. In addition Lake Koocanusa became a nutrient sink, stripping the downstream Kootenai River of 63% of its nitrates and 25% of the phosphates (Woods 1982, Snyder and Minshall 1996).

My objective was to examine changes to the fish community in a reach of the Kootenai River, Idaho, beginning shortly after initial operation of Libby Dam to nearly 20 years later. I also compared the differences in population density and growth of mountain whitefish (Prosopium williamsoni) in 1993 and 1994 to those of Partridge (1983) and other more recent studies (Downs 1998, 1999). From this information and literature I inferred possible reasons for changes in biomass and species composition within the fish community and changes in mountain whitefish density and growth.

## STUDY AREA

The Kootenai River is one of the largest tributaries of the Columbia River, originating in Kootenay[a] National Park, British Columbia, and with a drainage area of 49,987 km$^2$ (Bonde and Bush 1975; Figure 1). Libby Dam; on the Kootenai River near Jennings, Montana, was constructed for flood control and hydropower. The resultant reservoir, Lake Koocanusa, was completely filled by 1974, and the first turbines went on line in 1975 (May et al. 1980).

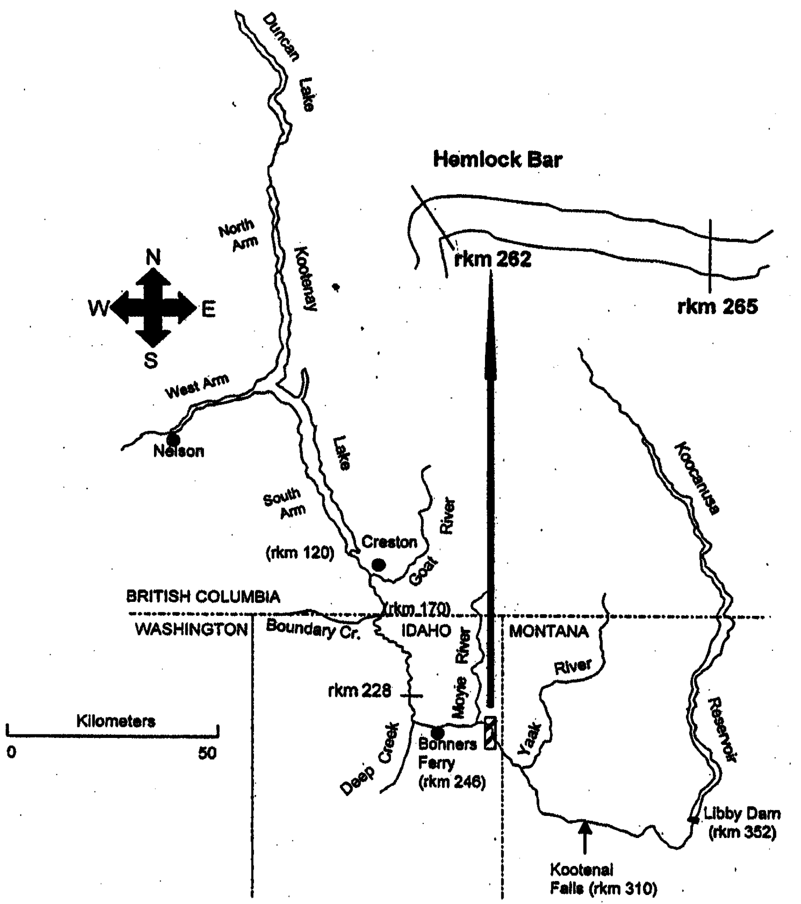


Figure 1. Location of the Kootenai River, Kootenay Lake, Lake Koocanusa, Libby Dam, Bonners Ferry, and important points. The river distances from the northernmost reach of Kootenay Lake are in river kilometers (rkm) and are indicated at important points. The Hemlock Bar reach is marked by cross-hatching.

[a] Kootenai is spelled Kootenay in Canada.

In 1993 and 1994, I sampled rainbow trout (O. mykiss) and mountain whitefish within a 3.2-km (29.4 ha) reach (rkm 262-265.2) located within the Kootenai River canyon in Idaho, locally known as the Hemlock Bar (Figure 1). In 1994 I also sampled all species of fish within a 1.0-km reach within this area to compare the fish community to that of a sample collected in 1980 by Partridge (1983). This reach was also sampled by Partridge (1983) for rainbow trout and mountain whitefish and is typical of the habitat thought to be preferred by salmonids in the Idaho section of the river. The reach is about 2-3 m in depth, but pools at the lower and upper ends of the reach are about 12 and 30 m deep, respectively. Substrate is gravel, cobble, and boulders.

## METHODS

### *Relative Abundance and Fish Community*

In 1980 fish populations were sampled with a single pass on each shoreline during the night with boat-mounted electrofishing gear (Partridge 1983). The 1.0-km section of river at the Hemlock Bar was electrofished to document the fish community composition and biomass. All species and sizes of fish were recorded, regardless of size, but effort was not noted. In 1994 the same 1-km reach was electrofished at night during August with an 8-m boat equipped with a 230 V DC Smith Root electroshocker adjusted to generate 5 amps. All fish were netted regardless of size, identified, and weighed (g). A single nighttime pass along each 1.0-km shoreline of the reach was completed, and the elapsed electrofishing time was recorded.

### *Mountain Whitefish Population Estimates*

In 1980 and 1981, population estimates of mountain whitefish age I and older in the 3.2-km Hemlock Bar reach were calculated by mark-recapture methods described by May and Huston (1979), a modification of the Schnable multiple-trial mark and recapture method (Ricker 1975). Two nighttime trials were used to mark mountain whitefish, followed 7 d later by two recapture periods. Estimates were expressed as mountain whitefish / 305 m of river length. In 1993 and 1994, population estimates of age 1 and older mountain whitefish within' the Hemlock Bar reach were calculated using the Chapman modification of the Schnable multiple-trial mark and recapture method (Ricker 1975).

### *Mountain Whitefish Age and Growth*

Age I and older mountain whitefish captured during electrofishing in April 1980 and August 1980-1982 were measured total length mm (TL), *and* scale samples were taken to determine growth rates (Partridge 1983). Scale impressions were made on acetate slides and viewed on a micro-projector at 40X. Mountain whitefish length at time of scale annulus formation was estimated by using a straight-line nomograph, and for those collected during spring the total length at capture before annulus formation was used for the last growth increment at age and time of collection (Carlander 1950). In 1993-1994 I used the same procedure to assess mountain whitefish age and growth. Additionally, length at age was determined using the Lee method (Ricker 1975).

## RESULTS

### *Relative Abundance and Fish Community*

Partridge (1983) collected seven species of fish in his single trial sample in 1980 from the 1-km section of the Hemlock Bar for a total catch of 485 fish and biomass of 137 kg (Table 1). Mountain whitefish were most abundant (70% of the catch) followed by largescale sucker (Catostomus macrocheilus; 19%). Mountain whitefish and largescale sucker were nearly equal in biomass at 58 (42%) and 67 (49%) kg, respectively. I used proportions for comparisons of biomass because catch per unit of effort information was not available for the Partridge (1983) study. Electrofishing in August 1994 in the same 1-km reach resulted in a total catch of 194 fish and a total biomass of 56 kg, which comprised eight species. Mountain whitefish was the most abundant species (40%). Biomass was comprised primarily of largescale sucker; 39 kg (70%), followed by mountain whitefish (19%) and northern pikeminnow (Ptychocheilus oregonensis) at 3.7%.

### *Mountain Whitefish Population Estimates*

In September *1980,* Partridge (1983) estimated a density of 1,533 mountain whitefish / 305 m of river (N = 2,123; 80% C.I. = 1,295-1,771), and in September 1981 he estimated 1,331 mountain whitefish / 305 m (N = 1,876; 80% C.I. = 1,115-1,547). In September 1993, I estimated 353 mountain whitefish / 305 m of river (N = 1,373; 95% C.I. = 341-365), and in September of 1994 I estimated 714 mountain whitefish / 305 m of river (N = 1,757; 95% C.I. = 697-731).

### *Mountain Whitefish Age and Growth*

Partridge *(1983)* estimated that total lengths of mountain whitefish at annulus formation were 116, 222, 280, 327, and 393 mm TL for ages 1-5 (N = 371), respectively (Figure 2). In 1994, I estimated that mountain whitefish lengths at annulus were 91, 123, 140, 174, 199, 250, and 300 mm TL for ages 1-7 (N = 159), respectively.

Table 1. Single pass electrofishing catch and catch per unit of effort (CPUE; h) from the Hemlock Bar reach of the Kootenai River, August 1994 and April 1980.

| Species | 1994 | | | 1980 | |
|---|---|---|---|---|---|
| | N | Weight (kg) | CPUE | N | Weight (kg) |
| Mountain whitefish (Prosopium williamsoni) | 77 | 10.61 | 179 | 340 | 58.2 |
| Rainbow trout (Oncorhynchus mykiss) | 3 | 0.63 | 7 | 13 | 4.5 |
| Kokanee (O. nerka) | 2 | 0.20 | 5 | 0 | -- |
| Bull trout (Salvelinus confluentus) | 0 | -- | -- | 1 | 0.4 |
| Peamouth (Mylocheilus caurinus) | 10 | 1.16 | 23 | 34 | 6.2 |
| Longnose sucker (Catostomus catostomus) | 4 | 1.90 | 9 | 0 | -- |
| Largescale sucker (C. macrocheilus) | 54 | 39.14 | 126 | 90 | 66.6 |
| Redside shiner (Richardsonius balteatus) | 27 | 0.23 | 63 | 1 | 0.1 |
| Northern pikeminnow (Ptychocheilus oregonensis) | 17 | 2.10 | 40 | 6 | 1.5 |
| Total | 194 | 55.97 | | 485 | 137.4 |

## DISCUSSION

A substantial change occurred in the fish community within the Hemlock Bar reach of the Kootenai River post-Libby Dam. The most notable change was the reduced proportion of mountain whitefish biomass and to a lesser extent rainbow trout. Since construction and operation of Libby dam, several ecosystem-based studies of the Kootenai River have been undertaken (Northcote *1973,* Daley et al. 1981, Woods *1982,* Snyder and Minshall 1996, Hauer and Stanford *1997). These* studies provide circumstantial evidence that ecosystem disturbance by the construction of Libby Dam, power peaking, regulated and reduced flushing flows, and the nutrient sink effect of Lake Koocanusa are ail likely reasons for these changes, and these changes are not unusual (Ney 1996). Changes in the fish communities in rivers of Iowa were usually indicative of environmental alterations to river ecosystems (Paragamian 1990).

Impoundment of Lake Koocanusa is responsible for the reduction of nutrients in the lower Kootenai River and is responsible for lower primary production (Snyder and Minshall 1996). 1 believe the lower productivity contributed to slower growth, lower standing stocks, reduced carrying capacity, and changes in the fish community biomass. Over the past 30 years, the Kootenai system has reversed from a system with excess nutrients to one of nutrient depravation. (Northcote 1973, Daley et al. 1981). Although productivity in the Kootenai River remains high immediately below the dam, the decrease in downstream productivity is nearly exponential. Nutrients are also seriously depleted by the time the water of the Kootenai River reaches Idaho (Woods 1982, Snyder and Minshall 1996).

The fish community of the Hemlock Bar in 1980 (Partridge 1983) was comprised almost equally of mountain whitefish, an insectivore, and largescale sucker, an omnivore (Brown 1971, Wydoski and Whitney 1979, Simpson and Wallace 1982, Baxter and Stone 1995, Li et al. 1987). 1 believe the 1980 sample of the fish community was similar to the pre-Libby Dam community, based on the delayed latent effects of impoundment (Baxter 1977, Yurk and Ney 1989, Ney et al. 1990, Ney 1996). Apparently changes within the ecosystem after impoundment were less tolerable to the insectivore than the omnivore because the fish community sampled in 1994 indicated a shift to a biomass dominance of largescale sucker and substantially fewer mountain whitefish, while the total catch of each decreased. The reduced density of mountain whitefish is supported by chronological decreases in population densities. Partridge (1983) estimated 1,533 and 1,331 mountain whitefish / 305 m of river in September of 1980 and 1981, respectively. By 1993 and 1994, mountain whitefish abundance had declined to an estimated 353 and 714 fish / 305 m of river. Estimate for September 1998 and 1999, over 20 years after closing of Libby Dam, were 309 and 381 mountain whitefish / 305 m of river (Downs 1998, 1999). These estimates suggest that there was a minimum of a two- to four-fold decrease in mountain whitefish numbers.

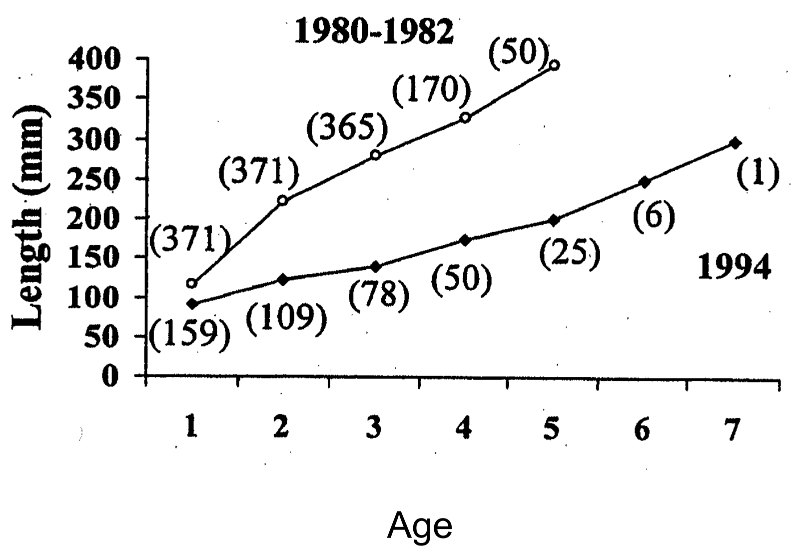


Figure 2. Back calculated length at age of mountain whitefish in the Kootenai River, Idaho, from the Hemlock Bar reach. Samples are from 1980-1982 and 1993-1994; sample sizes by age are subtended.

The change in the fish community form one equally represented by mountain whitefish and largescale sucker to a community dominated by largescale sucker may be food related and further explained by lack of flushing flows, which has resulted in armoring of interstitial spaces and a loss in habitat heterogeneity. Hauer and Stanford (1997) found a change in the species composition in the Kootenai River benthos with reduced numbers of Plecoptera and Trichoptera. These reduced numbers equate to reduced food abundance for insectivores like rainbow trout and mountain whitefish that may feed on insects in the water column (Brown 1971, Wydoski and Whitney 1979, Simpson and Wallace 1982, Baxter and Stone 1995). This change has also resulted in reduced productivity and probably has affected numbers of Plecoptera and Trichoptera through loss of habitat (Hauer and Stanford I997).

Furthermore, Libby Dam has been operated as a power peaking facility (Paragamian et al. 2000) resulting in dewatering of the varial zone and reduced secondary productivity (pers. comm., Brian Marotz, Montana Fish, Wildlife and Parks). Variation in stream discharge has been known to cause changes in invertebrate abundance, productivity, and species composition below dams (Cushman 1985). Trotzky and Gregory (1974) found low discharges below a power dam resulted in dewatered side channels and resulted in reduced aquatic insect biomass. Rimmer (1985) artificially reduced discharge in seminatural river channels and depressed growth of rainbow trout. McKinney et al. (2001) found stabilization of the flow regime below the Glen Canyon Dam, Colorado River-Arizona, after years of operation with power peaking, helped support an increase in abundance of rainbow trout and improved survival. A minimum *flow* requirement for the Susquehanna River below the Conowingo Dam, Maryland, resulted in an improvement in growth and condition of three fish species (Weisberg and Burton 1993).

Ecosystem disturbances post-Libby Dam may have also affected growth of mountain whitefish. I found back-calculated growth of *mountain whitefish* sampled in 1994 to be slower than growth in the late 1970s (Partridge 1983). The slower growth of mountain whitefish could not be due to increased densities because densities are now several fold lower. The slower growth is most likely due to the lower productivity/carrying capacity of the Kootenai River.

Differences in sampling season may bias the comparisons of my fish community observations in summer 1994 to Partridge's findings in spring 1980. Although I do not believe it was a substantial factor, there could have been some differences in gonadal development in some fishes. If there were a notable bias, it would have been an underestimate in the biomass proportion of mountain whitefish, a winter spawner (McPhail and Lindsey 1970), for spring 1980. Shortly after the operation of Libby Dam began, Partridge (1983) calculated a late winter (March) 1981 population of 614 mountain whitefish / 305 m of river; by late September, the density was 1,331 fish / 305 m. Partridge (1983) reported seeing large numbers of mountain whitefish ascending the Moyie River on a suspected spawning run during the previous fall. It is likely that the late winter estimate of mountain whitefish was lower because some fish had not returned from spawning locations in tributaries; it is likely that these fish had returned to the reach by April. Mountain whitefish in the Sheep River system of Alberta (a drainage bounding the Kootenai drainage) are known to travel as far as 60 km to spawning tributaries in mid October and return by April to the main stem river (Davies and Thompson 1976).

If rehabilitation of the Kootenai River fish community to pre-dam biomass, including that of the sportfish, becomes a management objective, its success will depend on a cooperative approach by managing agencies. I believe biomass and growth conditions can be improved by eliminating power peaking, improving flushing flows, and restoring nutrients (Weisberg et al. 1993, Travnichek et al. 1995, Wilson 1999, McKinney et al, 2001), but complete restoration is unlikely unless the Kootenai River is restored to a free flowing system.


## ACKNOWLEDGEMENTS

I would like to thank Fred Partridge of the Idaho Department of Fish and Game (IDFG) for his initial work on the Kootenai River that set the framework for subsequent studies. I thank Pat Marcuson and Gretchen Kruse of the IDFG for help with data collection and Vint Whitman (IDFG) for the preparation of figures. Thanks to Jack Siple, Larry Aitken, and Paul Anders of the Kootenai Tribe of Idaho for their assistance with electrofishing. I also thank Steve Yundt and Jody Walters of the IDFG for their helpful critical reviews of this manuscript and John J. Ney of Virginia Tech for helpful discussions. The Bonneville Power Administration provided funds for this investigation.


## LITERATURE CITED


Anonymous. 1996. History of diking on the Kootenay River floodplain in British Columbia. Redwing Naturalists, Prepared for Habitat Enhancement Branch, Department of Fisheries and Oceans, Vancouver.

Apperson, K. 1990. Kootenai River white sturgeon investigations and experimental culture. Idaho Department of Fish and Game. Prepared for Bonneville Power Administration. Annual Progress Report, Project 88-65, Boise.

Bain, M.B., J. T. Finn, and H.E. Booke. 1988. Stream-flow regulation and fish community structure. Ecology 69:382-392.

Baxter, *R. M.* 1977. Environmental effects of dams and impoundments. Annual Reviews in Ecological Systems 255-283.

Baxter, G. T. and M. D. Stone. 1995. Fishes of Wyoming. Wyoming Game and Fish Department. Cheyenne.

Benenati, P.L., J.P. Shannon, and D. W. Blinn. 1998. Desiccation and recolonization of phytobenthos in a regulated desert river: Colorado River at Lee's Ferry, Arizona, USA. Regulated Rivers: Research and Management 14:519-532.

Bonde, T. H. and R. M. Bush. 1975. Kootenai River water quality investigations, Libby Dam preimpoundment study 1967 - 1972. U.S. Army Corps of Engineers; Washington, D.C.

Brown, C. J. D. 1971. Fishes of Montana. Big Sky Books, Montana State University, Bozeman.

Carlander, K. D. 1950. Some considerations in the use of fish growth data based upon scale studies. . Transactions of the American Fisheries Society 79:187-194.

Cushman, R.M. 1985. Review of ecological effects of rapidly varying flows downstream from hydroelectric facilities. Transactions of the American Fisheries Society 5:330-339.

Davies, R. W. and G. W. Thompson. 1976. Movements of mountain whitefish (*Prosopium williamsoni*) in the Sheep River watershed, Alberta. Journal of the Fisheries Research Board Canada 33:2,395-2,401.

Daley, R.J., E.C. Carmack, C.B. Gray, C.H. Pharo, S. Jasper, and R.C. Wiegland. 1981. The effects of upstream impoundments on Kootenay Lake, B.C., Canada Inland Waters Directorate, Research Institute, Scientific Series, West Vancouver.

Downs, C. 1998. Kootenai River Fisheries Investigations; Rainbow Trout Recruitment. Idaho Department of Fish and Game. Prepared for Bonneville Power Administration. Annual Progress Report, Project 88-65, Boise.

Downs, C. 1999. Kootenai River Fisheries Investigations; Rainbow Trout Recruitment. Idaho Department of Fish and Game. Prepared for Bonneville Power Administration. Annual Progress Report, Project 88-65, Boise.

Hauer, F. R. and J. A. Stanford. 1997. Long-term effects of Libby Dam operation on the ecology of macrozoobenthos of the Kootenai River, Montana and Idaho. Montana Fish Wildlife and Parks, Helena.

Li, H. W., C. E. Shreck, C. E. Bond, and E. Rexstad. 1987. Factors influencing changes in fish assemblages of Pacific Northwest streams. Pages 193-202*, in* W.J Mathews and D.C. Heins (editors) Community and evolutionary ecology of North American Stream Fishes, University of Oklahoma Press, Norman and London.

May, B. and J. Huston. 1979. Kootenai River Investigations. Final Job Report, Contract DACW 67-76-C-0055, Fisheries Division, Montana Department of Fish Wildlife and Parks, Helena.

May, B., S. Appert, and J. Huston. 1980. Kootenai River Investigations. Annual Progress Report, Contract DACW 67-79-C-0112, Fisheries Division, Montana Department of Fish, Wildlife, and Parks, Helena.

McKinney, T., D. W. Speas, R. S. Rogers, and W. R. Persons. 2001. Rainbow trout in a regulated river below Glen Canyon Dam, Arizona, following increased minimum flows and reduced discharge variability. North American Journal of Fisheries Management 21:216-222.

McPhail, J. D. and C. C. Lindsey. 1970. Freshwater fishes of northwestern Canada and Alaska. Journal of the Fisheries Research Board Canada; Ottawa.

Ney, J. J. 1996. Oligotrophication and its discontents: effects of reduced nutrient loading on reservoir fisheries. Transactions of the American Fisheries Society 16:285-295.

Ney, J. J., C. M. Moore, M. S. Tisa, J. J. Yurk, and R. J. Neves. 1990. Factors affecting the sport fishery in a multiple-use Virginia reservoir. Lake and Reservoir Management 6:21-32.

Northcote T.G. 1973. Some impacts of man on Kootenay Lake and its salmonids. Great lakes Fishery Commission, Technical Report Number 25. Ann Arbor

Paragamian, V.L. 1990. Fish populations of Iowa rivers and streams. Technical Bulletin Number 3. Iowa Department of Natural Resources, Des Moines.

Paragamian, V. L. 2000. The effects of variable flows on burbot spawning migrations in the Kootenai River, Idaho, USA, and British Columbia, Canada. Pages 111-123 *in* V. L. Paragamian and D. W. Willis, Editors. Burbot: biology; ecology, and management. American Fisheries Society, Fisheries Management Section, Publication Number 1, Bethesda.

Paragamian, V. L., V. Whitman, J. Hammond, and H. Andrusak. 2000. Colapse of the burbot fisheries in Kootenay Lake, British Columbia Canada, and the Kootenai River, Idaho, USA, post-Libby Dam. Pages 155-164 in V. L. Paragamian and D. W. Willis, editors. Burbot: biology, ecology, and management: Fisheries Management Section, American Fisheries Society, Publication Number 1, Bethesda.

Partridge, F. 1983. Kootenai River fisheries investigations. Idaho Department of Fish and Game, Federal Aid in Sport Fish Restoration, Project F-73-R-5, Completion Report, Boise.

Peňáz, M., B. Vlastimil, and P. Miroslav. 1999. Changes in the structure of fish assemblages in a river used for energy production. Regulated Rivers Research and Management 15:169-180.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada, Bulletin 191, Ottawa.

Rimmer, J.B. 1985. Effects of reduced discharge on production and distribution of age-0 rainbow trout in serninatural channels. Transactions of the American Fisheries Society 114:388-396.
Simpson, J. and R. Wallace. 1982. Fishes of Idaho. The University Press of Idaho, Moscow.
Snyder, E.B. and G.W. Minshall. 1996. Ecosystem metabolism and nutrient dynamics in the Kootenai River in relation to impoundment and flow enhancement for fisheries management. Completion Report. Stream Ecology Center, Idaho State University, Pocatello.
Travnichek, V.H., M.B. Bain, and M.J. Maceina. 1995. Recovery of a warmwater fish assemblage after the initiation of a minimum-flow release downstream from a hydroelectric dam. Transactions of the American Fisheries Society 124:836-844.
Trotsky, H. *M. and* R. W. Gregory. 1974. The effects of water flow manipulation below a hydroelectric power dam on the bottom fauna of the upper Kennebec River, Maine. Transactions of the American Fisheries Society 103:318-324.
Weisberg, S.B. and W.H. Burton. 1993. Enhancement of fish feeding and growth after an increase in minimum flow below the Conowingo Dam. North American Journal of Fisheries Management 13:103-109.
Wilson, G, K. Ashley, S. Mouldey, Ewing, P, Slaney, and R. Land. 1999. Development of a premier river fishery: the Big Silver Creek experiment, 1993-1997. Final Report, Fisheries Project Report Number RD 69, British Columbia Ministry of Fisheries Research and Development, Vancouver.
Woods, P.F. 1982. Annual nutrient loadings, primary productivity, and trophic state of Lake Koocanusa, Montana and British Columbia, 1972-80. Geologic Survey Professional Paper 1238, United States Government Printing Office, Washington, D.C.
Wydoski, R. S. and R. R. Whitney. 1979. Inland fishes of Washington. University of Washington Press, Seattle.
Yurk, J. J. and J. J. Ney. 1989. Phosphorus-fish community biomass relationships in southern Appalachian reservoirs: can lakes be too clean? Lake and Reservoir Management 5:83-90.

**Received: 10 December 2001**



**Accepted: 20 February 2002**